0S1 METROLOGY GAUGES

JPL

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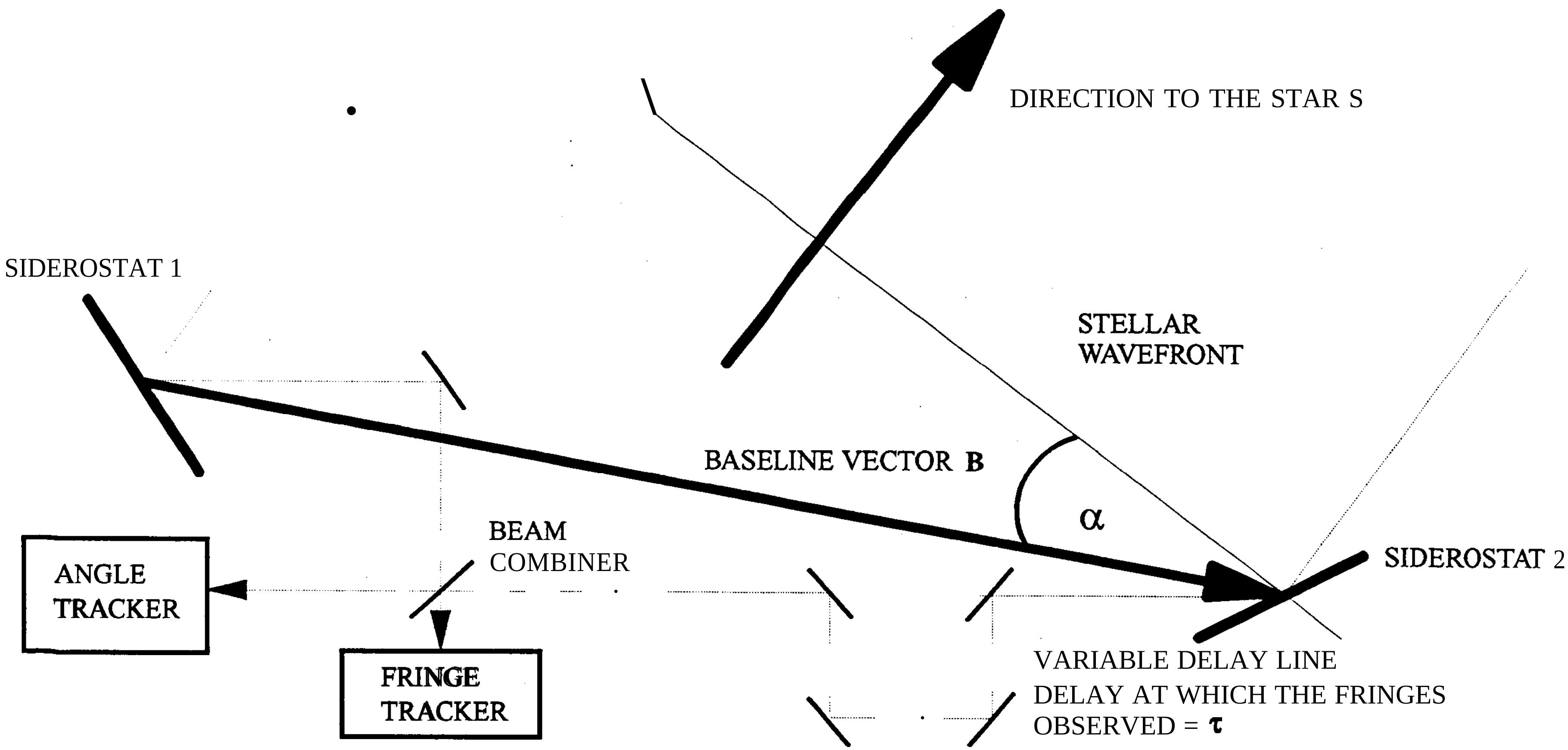
INTRODUCTION

- 0S1 requires a metrology system to measure the three dimensional baseline vector between any two of its siderostats and the distance from the beam combiner to the baseline end points.

$$\tau = \mathbf{B} \cdot \mathbf{S} = |\mathbf{B}| \sin\alpha$$



LASER METROLOGY GAUGES

- **The heterodyne interferometer is chosen as the basic metrology gauge for 0S1.**

- **Three variants of the basic metrology gauge need to be demonstrated:**

    - The NULL metrology gauge
    - The RELATIVE metrology gauge
    - The ABSOLUTE metrology gauge

ACHIEVEMENTS TO DATE

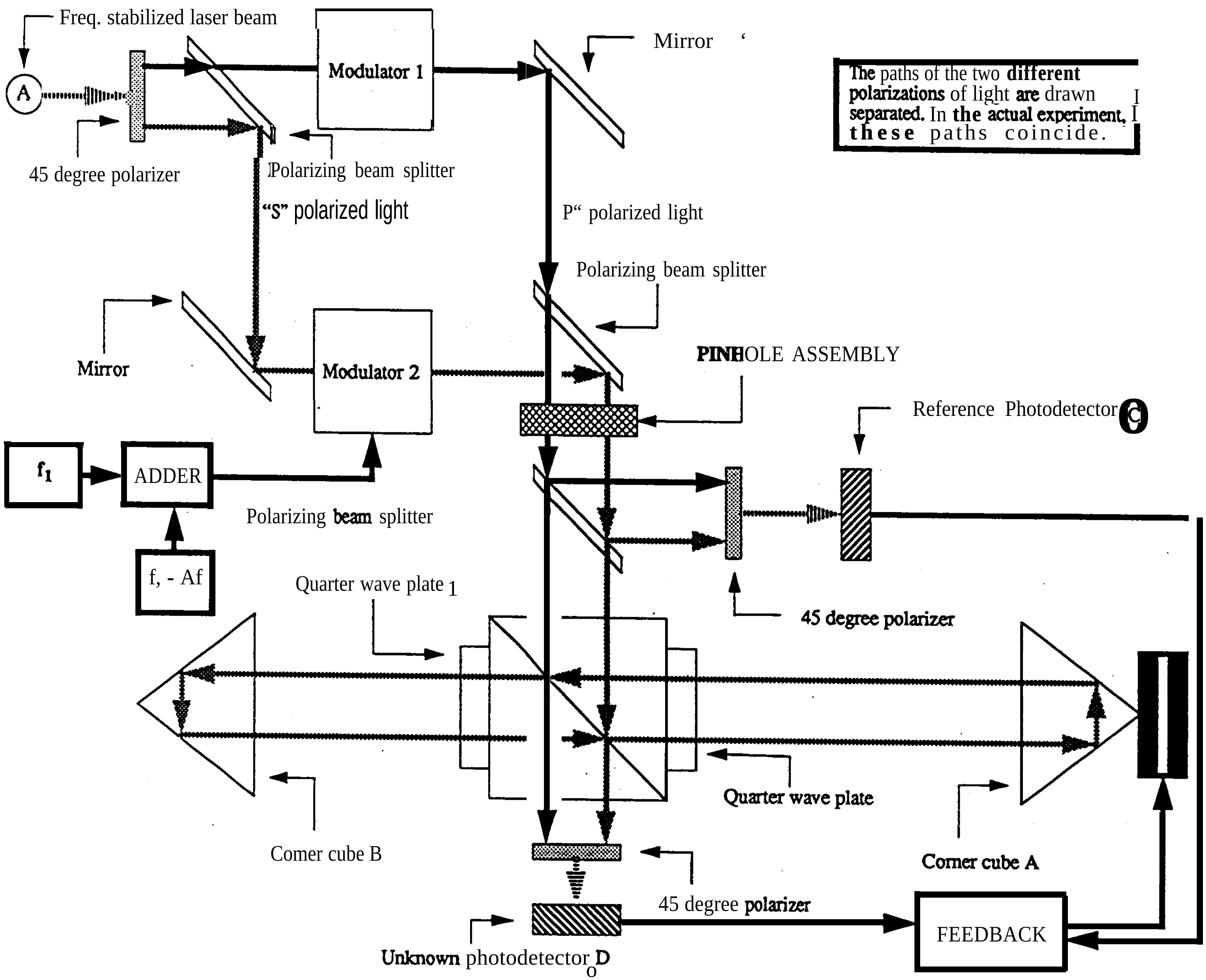
- **0S1 null metrology gauge has attained a precision of 0.6 picometers at time scales of 2500 seconds.**

- **0S1 relative metrology gauge has attained an accuracy of 31 picometers rms *in air.* In vacuum, we obtained an accuracy of 10 picometers rms. Further improvements to the gauge is in progress. Our new data sets indicate an accuracy of 3.5 pm rms over several wavelengths of motion.**

- **0S1 absolute metrology gauge will be implemented using an infrared laser. The laser has been stabilized to an external Fabry-Perot cavity to 1 part in 10^{10}. The cavity will be placed in an oven and the rest of the gauge will be implemented.**

NULL METROLOGY GAUGE

NULL METROLOGY INTERFEROMETER



Null Metrology (Apr 29f, 1992; 250K)

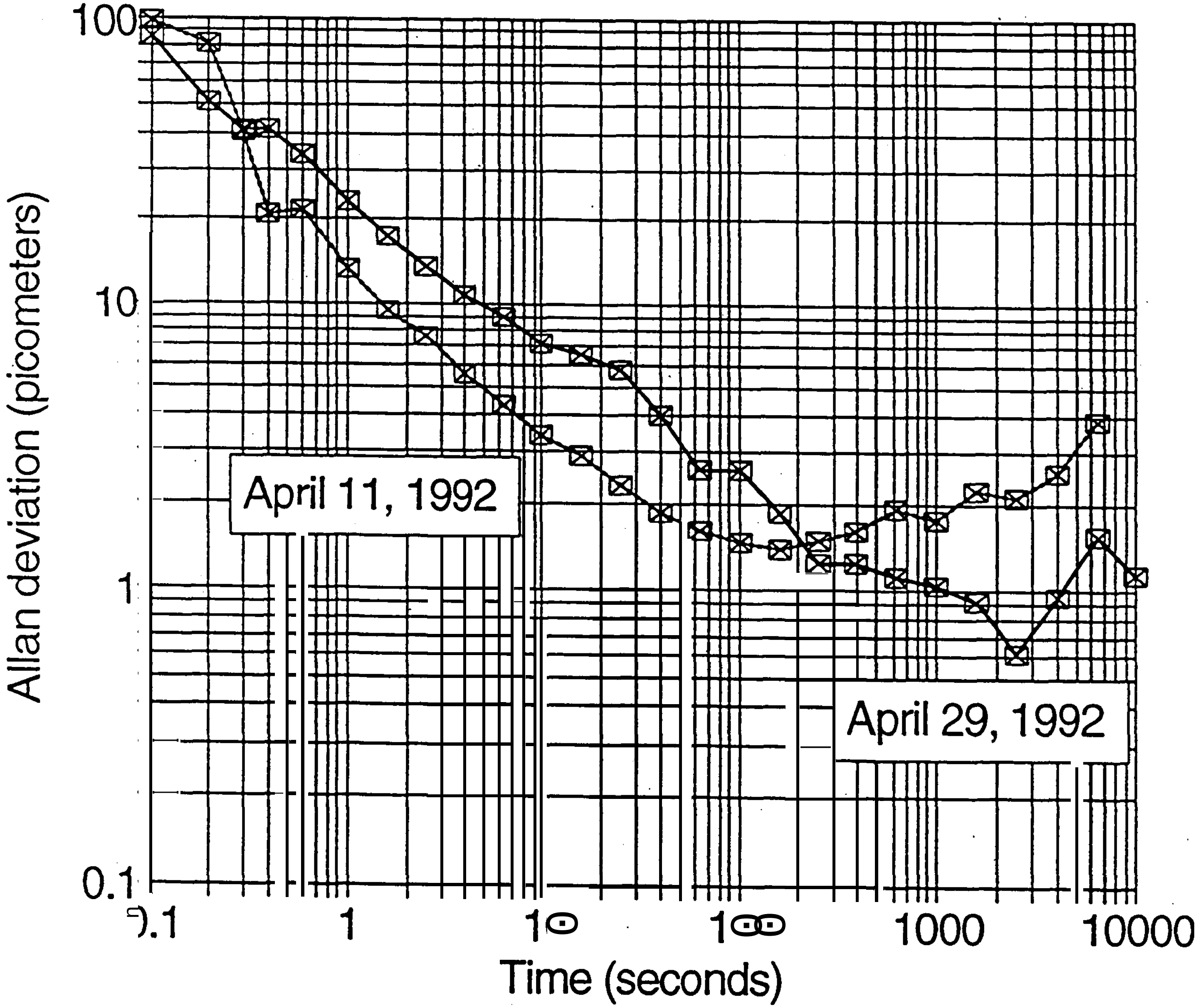


Figure 9

SUMMARY

- **Problems encountered:**

  . Spurious retro-reflection by optical surfaces and pin hole

  . Relative drift of the two interferometer electronics

- **Solutions:**

  . Tilt pinhole to avoid retro-reflection into the laser

  . Switch electronics between the two interferometers every **30** seconds.

- **Result: The Allan deviation of the difference between the outputs of the two interferometers reaches down to 0.6 pico-meters at an integration time of 2500 seconds.**

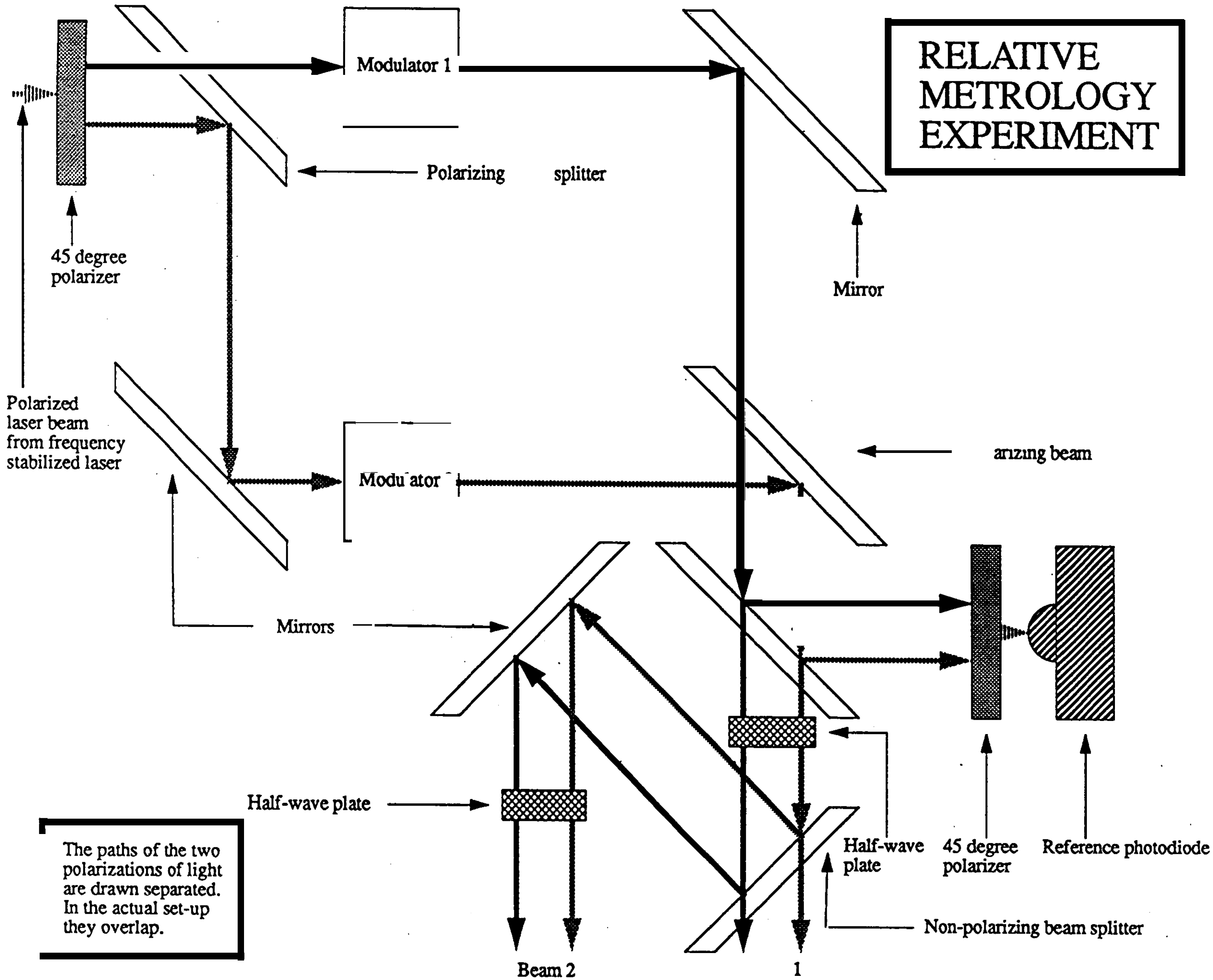
RELATIVE METROLOGY GAUGE

- **In the null metrology configuration in air, the systematic errors as well as the atmospheric effects cancel out.**

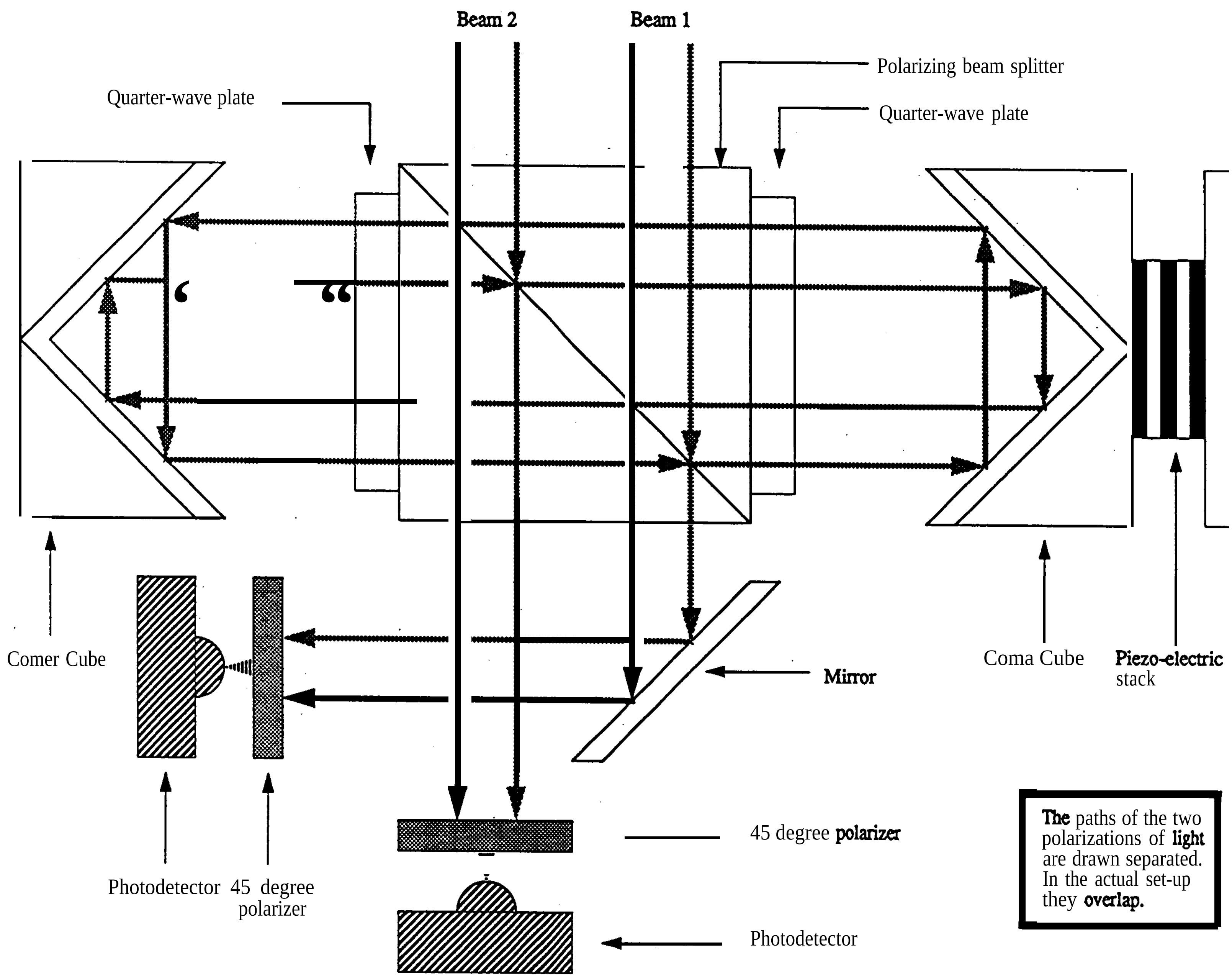
- **In order to test the accuracy of 0S1 metrology gauge, two interferometers with spatially separated beam-paths have been constructed to monitor the distance between two corner cubes.**

- **One of the corner cubes is moved through several wavelengths of light while monitoring the outputs of the interferometers.**

RELATIVE METROLOGY EXPERIMENT

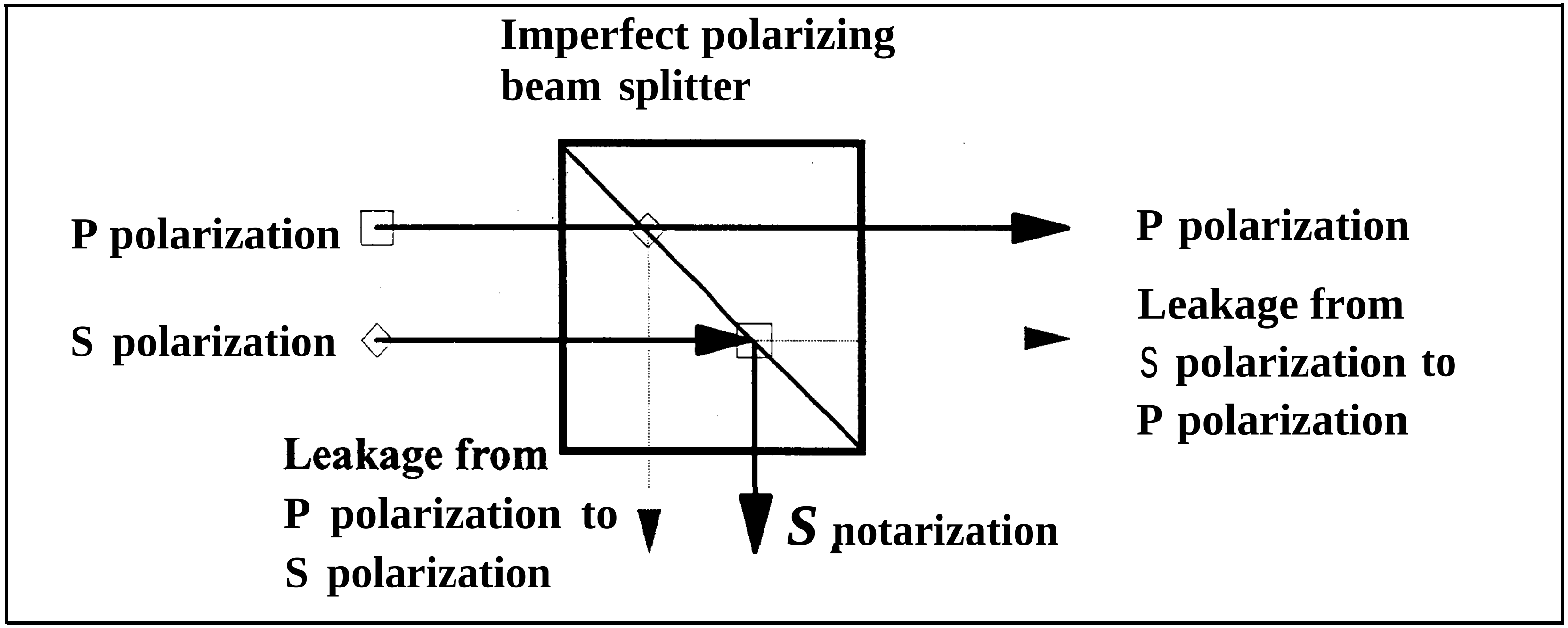


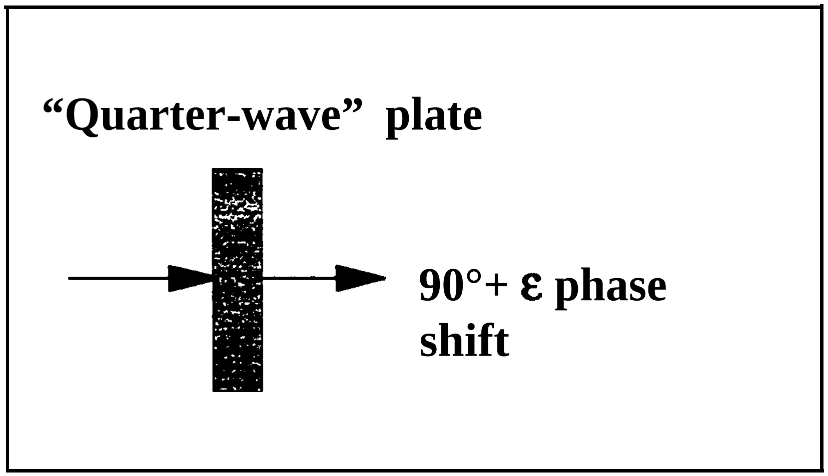
The paths of the two polarizations of light are drawn separated. In the actual set-up they overlap.

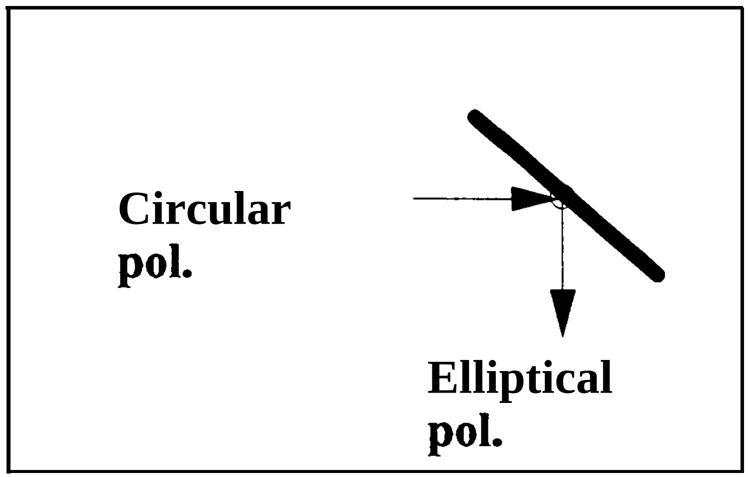


Beam 2
Beam 1
Polarizing beam splitter
Quarter-wave plate
Quarter-wave plate
Comer Cube
Mirror
Coma Cube
Piezo-electric stack
Photodetector
45 degree polarizer
45 degree polarizer
Photodetector
The paths of the two polarizations of light are drawn separated. In the actual set-up they overlap.

WHAT IS SELF-INTERFERENCE?

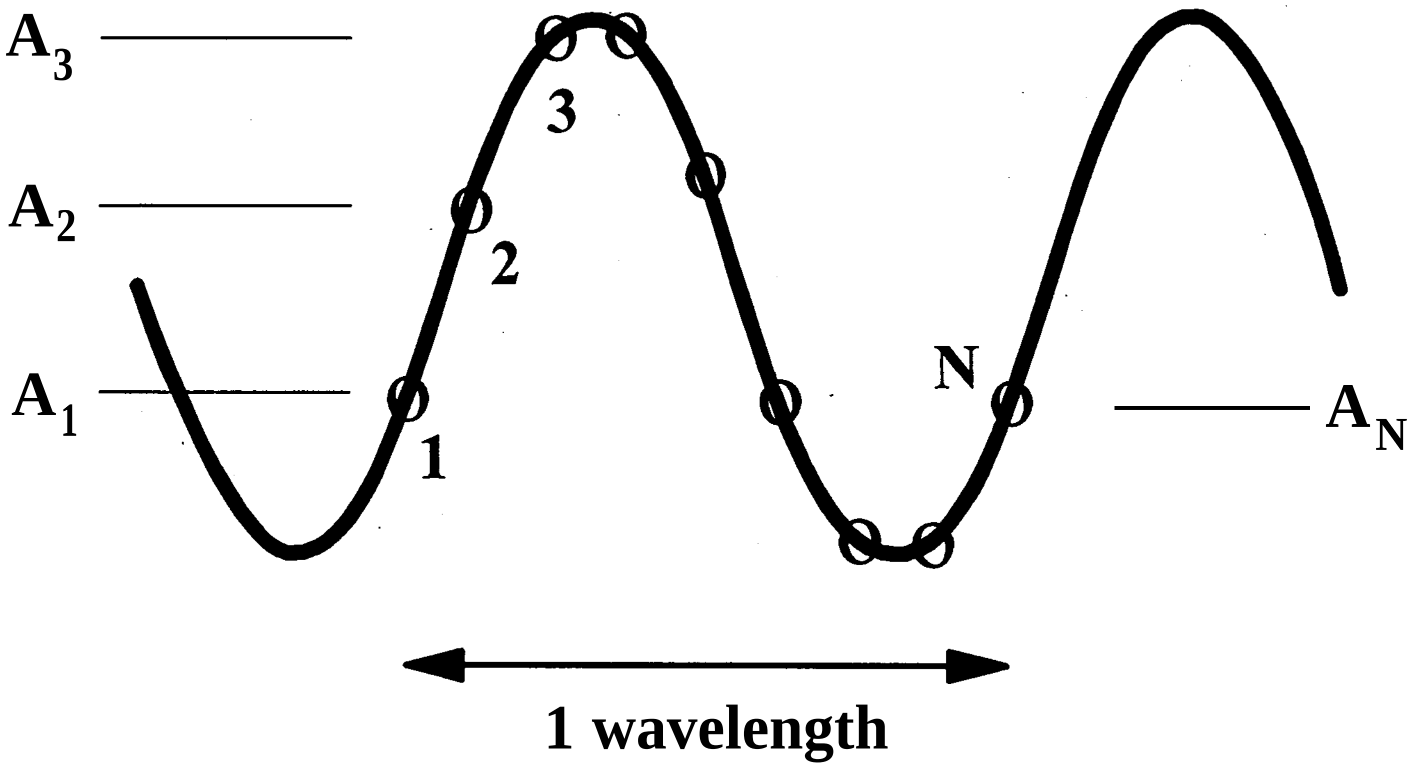






. These imperfections cause errors in the measurement which are periodic with the wavelength of the laser light.

CYCLIC AVERAGING

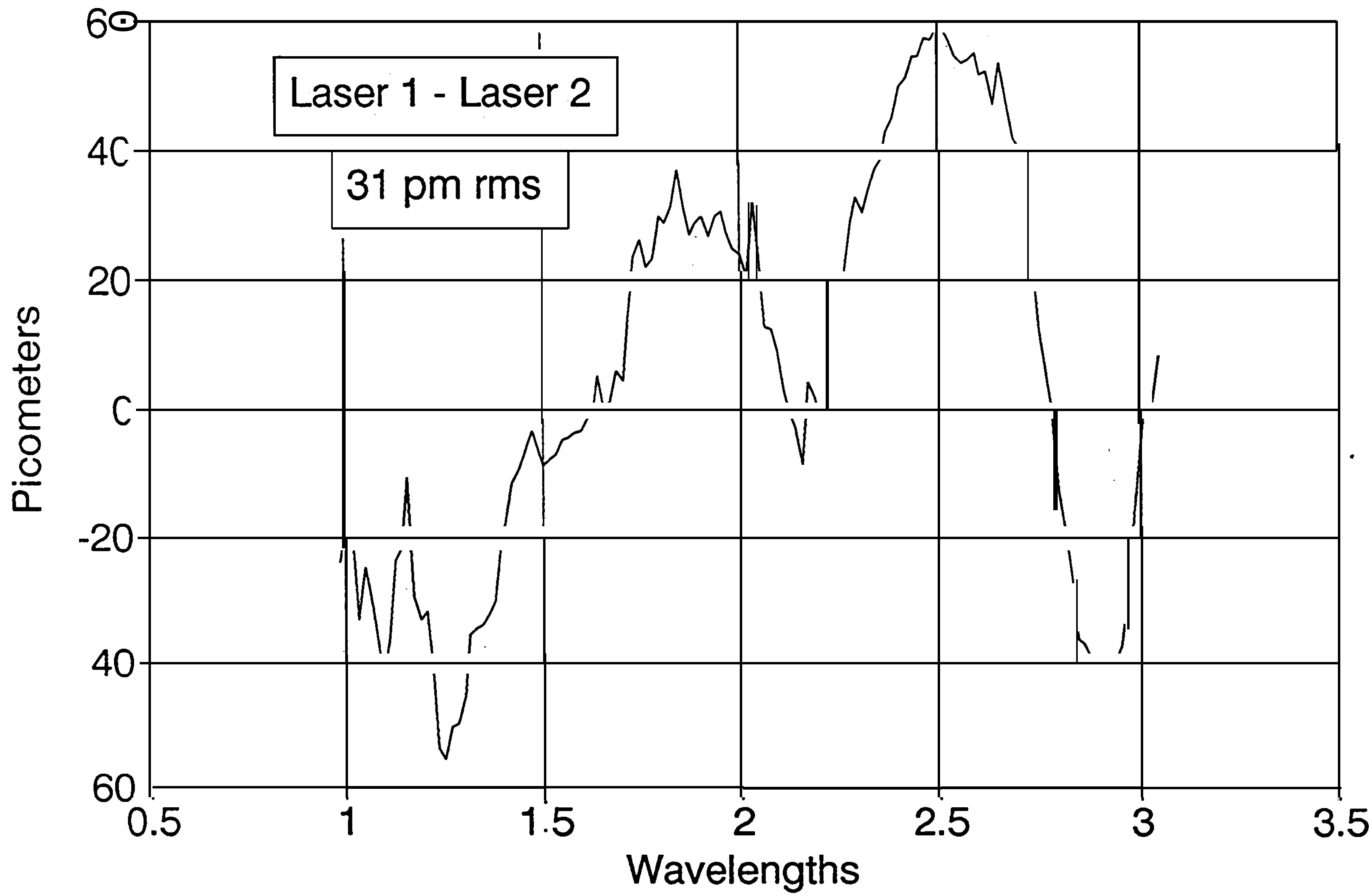


A_N = Amplitude at N = (A_1 + A_2 + A_3 + . . . + A_N) / N

. This procedure eliminates all systematic errors which are periodic with the wavelength of the laser light if there is a sufficient number of points.

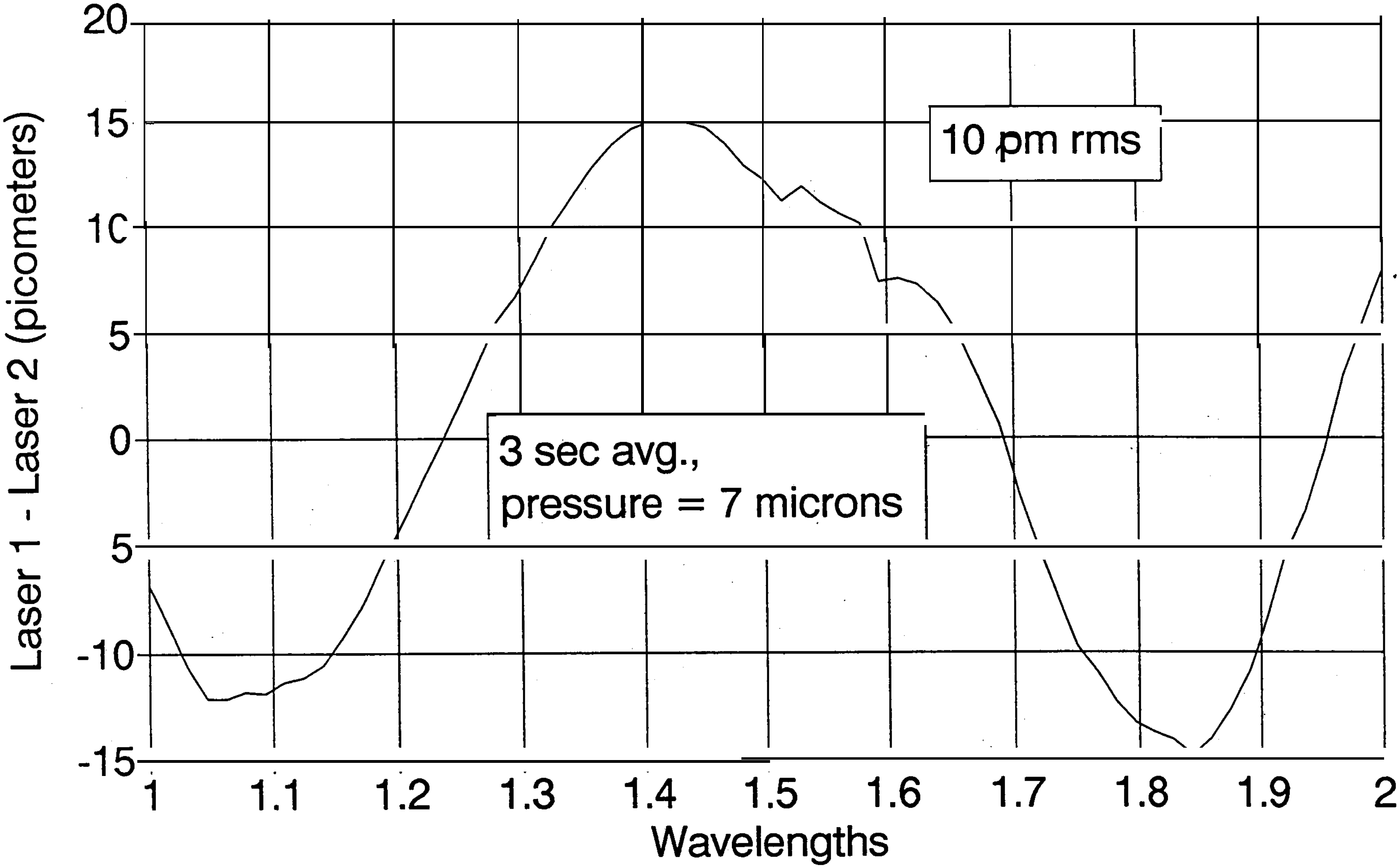
Relative Metrology 12/10/92B

(after self int. rem. and cyclic avg.)



Relative Metrology (03/17/1993B)

(with cyclic averaging)



SUMMARY

- **In 1991, we had obtained a difference of 700 picometers rms between the readings of the two interferometers for a corner-cube separation of 10 cm *in air* with cyclic averaging.**

- **In Dec. 1992, we obtained a difference of 31 picometers rms between the readings of the two interferometers for a corner cube separation of 75 cm in a closed vacuum chamber under atmospheric pressure with cyclic averaging.**

- **In March 1993, we obtained a difference of 10 picometers rms between the readings of the two interferometers for the same configuration *in vacuum* with cyclic averaging.**

- **In April 1993, our data sets indicate an rms difference of 3.5 picometers. Further analysis is in progress.**

ABSOLUTE METROLOGY GAUGE

- **The relative metrology gauge measures the changes in the distance between the corner cubes. The absolute metrology gauge measures the absolute distance between the corner cubes.**

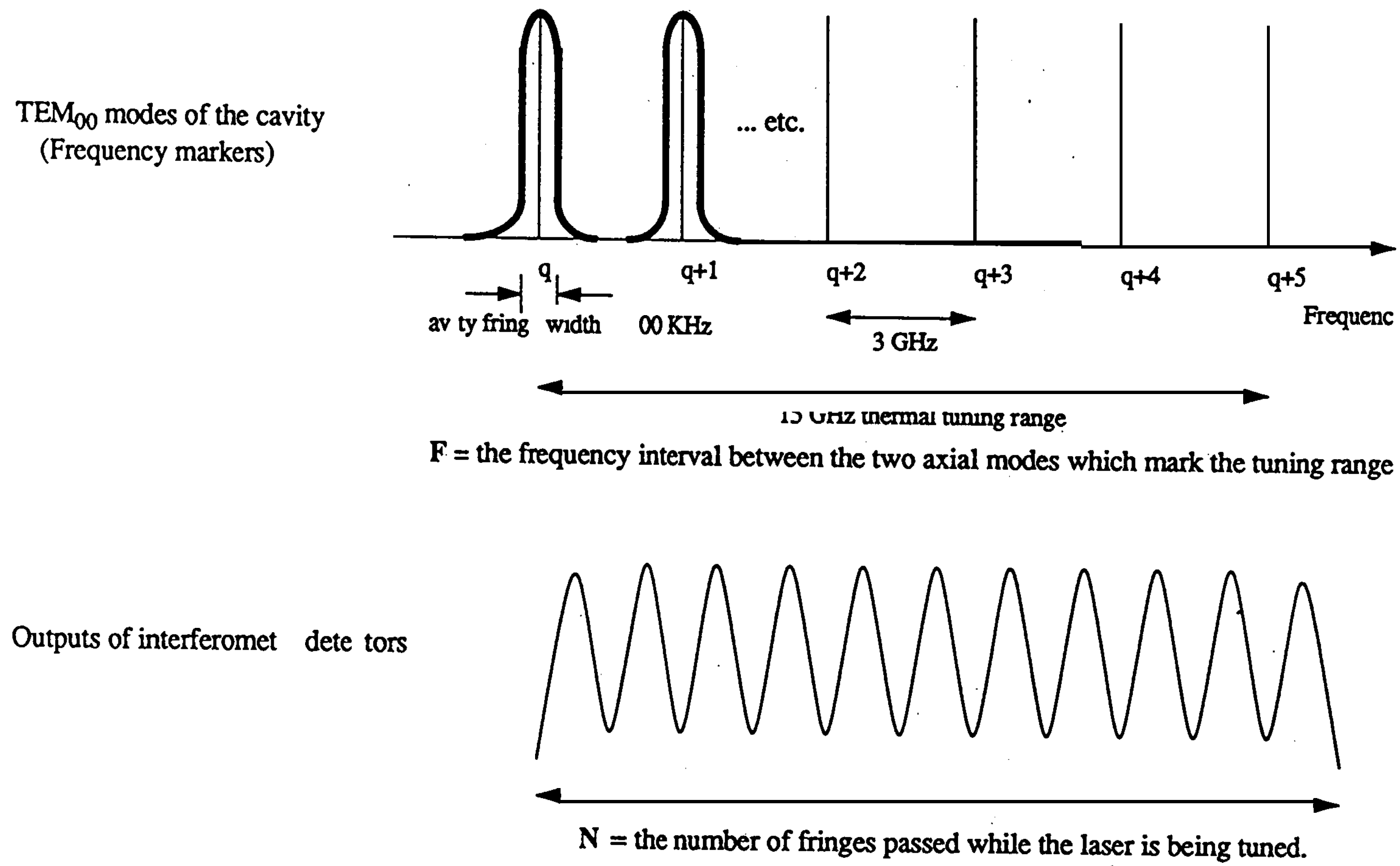
- **The 0S1 absolute metrology gauge will be implemented using an infrared laser.**

- **We have stabilized the absolute metrology laser to an external Fabry-Perot cavity to 1 part in 10^{10}.**

- **The cavity will be placed in an oven to control its length to the same level of accuracy per day.**

- **The absolute metrology experiment will be performed using the same set-up as the relative metrology experiment.**

ABSOLUTE METROLOGY EXPERIMENT



Then, the absolute length L is given by:

$$\boxed{L = c\,N/F}$$

where c is the speed of light.